Claims

What is claimed is:

1. A method for forming an image model, comprising the steps of:

    a. developing imaging system characteristics;

    b. developing gross shape;

    c. developing microstructure;

    d. incorporating the imaging system characteristics, the gross shape and the microstructure to form the image model.

2. The method of claim 1, wherein the imaging system characteristics are developed using a three-dimensional point spread function.

3. The method of claim 1, wherein the image model includes a data likelihood enabling a statistical inference to formulate underlying characteristics.

4. The method of claim 3, wherein the data likelihood is developed using image pixel based statistics.

5. The method of claim 4, wherein using the image pixel based statistics comprises the steps of:

    a. computing an amplitude mean value, an amplitude variance value and a ratio of the amplitude mean value to a standard deviation value at each image pixel to develop a statistical image characterizing tissue;

b. classifying each pixel as Rayleigh or Gaussian determined by the ratio of the amplitude mean value to the standard deviation value;

c. assigning a density function to each image pixel based upon the classification of each image pixel; and

d. constructing the data likelihood as a product of the density functions.

6. The method of claim 5, wherein constructing the data likelihood assumes an independence between each image pixel.

7. The method of claim 5, wherein the image model is physically-based and the order of the steps permits inclusion of the imaging system characteristics, the gross shape and the microstructure at each image pixel without violating the physical image model.

8. The method of claim 5, wherein computation of the amplitude mean and the amplitude variance value is non-trivial, requiring calculation of multiple integrals for each pixel.

9. The method of claim 5, wherein the density function describes an echo amplitude of a respective image pixel.

10. The method of claim 5, wherein the data likelihood is suitable for performing pose estimation.

11. The method of claim 1, wherein the imaging system characteristics are described by a point spread function.

12. The method of claim 1, wherein tissue is characterized by a reflectivity function.

13. The method of claim 12, wherein the reflectivity function comprises a sum of scaled three-dimensional delta functions.

14. The method of claim 1, wherein a radio frequency image is used for forming the image model, the radio frequency image represented by a sum of scaled and delayed point spread functions.

15. The method of claim 14, wherein tissue is characterized in the radio frequency image by a discrete scatterer model.

16. The method of claim 1, wherein the gross shape is described by a triangulated surface.

17. The method of claim 16, wherein the triangulated surface includes a set of triangular elements defined by respective vertices and edges of the triangular elements.

18. The method of claim 16, wherein acoustic properties of the triangulated surface are represented by multiple discrete scatterers distributed across the triangulated surface in a random model.

19. The method of claim 18, wherein spatial locations of the scatterers across the triangulated surface are parametrized by a scatterer concentration and a surface roughness.

20. The method of claim 19, wherein the surface roughness is modeled as a Guassian perturbation of each scatterer in a direction normal to the triangulated surface.

21. The method of claim 18, wherein each discrete scatterer is a sub-wavelength perturbation in the surface that scatters strongly in the direction of a transducer.

22. A method for forming a physically-based, probabilistic model for ultrasonic images, comprising the steps of:

a. creating a physical model of image formation; and

b. performing a representation of the physical model to form the probabilistic model.

23. The method of claim 22, wherein creating the physical model includes:

a. forming imaging system characteristics;

b. forming shape;

c. forming microstructure; and

d. incorporating the imaging system characteristics, the shape and the microstructure to create the physical model.

24. The method of claim 22, wherein the representation is a random phasor sum representation resulting from a linear model of a radio frequency image portion of the

physical model, the radio frequency image portion being characterized by a point spread function.

25. The method of claim 24, wherein tissue is characterized in the radio frequency image portion by a reflectivity function.

26. The method of claim 25, wherein tissue is characterized in the radio frequency image portion by a discrete scatterer model.

27. The method of claim 26, wherein the discrete scatterer model includes multiple discrete scatterers distributed across a surface of the gross shape.

28. The method of claim 27, wherein spatial location of the discrete scatterers distributed across the surface is parametrized by a scatterer concentration and a surface roughness.

29. The method of claim 27, wherein each discrete scatterer is a sub-wavelength perturbation in the surface that scatters strongly in the direction of a transducer

30. The method of claim 27, wherein each discrete scatterer contributes a phasor to the random phasor sum representation of the physical model.

31. The method of claim 23, wherein the microstructure is formed using image pixel-based statistics.

32. The method of claim 31, wherein using the image pixel-based statistics comprises the steps of:

a. computing an amplitude mean value, an amplitude variance value and a ratio of the amplitude mean to a standard deviation value at each image pixel to develop a statistical image characterizing tissue;

b. classifying each image pixel as Rayleigh or Gaussian depending on the ratio of the amplitude mean to the standard deviation value;

c. assigning a density function to each image pixel based upon the classification of each image pixel; and

d. constructing the data likelihood as a product of the density functions.

33. A method for forming a physically-based, probabilistic model for ultrasonic images, comprising the steps of:

a. creating a physical model of image formation, including:

i. formulating a deterministic description of imaging system characteristics,

ii. formulating a deterministic description of gross shape,

iii. formulating a random description of microstructure, and

iv. incorporating the imaging system characteristics, the gross shape and the microstructure to form the model; and

b. performing a random phasor sum representation of the physical model to form the probabilistic model.

34. A computer readable medium that configures a computer to perform a method that forms a physically-based, probabilistic model for ultrasonic images, the method comprising the steps of:

a. creating a physical model of image formation; and

b. performing a representation of the physical model to form the probabilistic model.

35. The computer readable medium of claim 34, wherein creating the physical model includes:

a. forming imaging system characteristics;

b. forming shape;

c. forming microstructure; and

d. incorporating the imaging system characteristics, the shape and the microstructure to create the physical model.

36. The computer readable medium of claim 34, wherein the representation is a random phasor sum representation resulting from a linear model of a radio frequency image portion of the physical model, the radio frequency image portion being characterized by a point spread function.

37. The computer readable medium of claim 36, wherein tissue is characterized in the radio frequency image portion by a reflectivity function.

38. The computer readable medium of claim 37, wherein tissue is characterized in the radio frequency image portion by a discrete scatterer model.

39. The computer readable medium of claim 38, wherein the discrete scatterer model includes multiple discrete scatterers distributed across a surface of the gross shape.

40. The computer readable medium of claim 39, wherein spatial location of the discrete scatterers distributed across the surface is parametrized by a scatterer concentration and a surface roughness.

41. The computer readable medium of claim 39, wherein each discrete scatterer is a sub-wavelength perturbation in the surface that scatters strongly in the direction of a transducer

42. The computer readable medium of claim 39, wherein each discrete scatterer contributes a phasor to the random phasor sum representation of the physical model.

43. The computer readable medium of claim 34, wherein the probabilistic model is formed using image pixel-based statistics.

44. The computer readable medium of claim 43, wherein using the image pixel-based statistics comprises the steps of:

a. computing an amplitude mean value, an amplitude variance value and a ratio of the amplitude mean to a standard deviation value at each image pixel to develop a statistical image characterizing tissue;

b. classifying each image pixel as Rayleigh or Gaussian depending on the ratio of the amplitude mean to the standard deviation value;

c. assigning a density function to each image pixel based upon the classification of each image pixel; and

d. constructing a data likelihood as a product of the density functions.

45. A computer readable medium that configures a computer to perform a method that forms an image model, the method comprising the steps of:

a. developing imaging system characteristics;

b. developing gross shape;

c. developing microstructure;

d. incorporating the imaging system characteristics, the gross shape and the microstructure to form the image model.

46. A computer readable medium that configures a computer to perform a method that forms a physically-based, probabilistic model for ultrasonic images, the method comprising the steps of:

a. creating a physical model of image formation, including:

i. formulating a deterministic description of imaging system characteristics,

ii. formulating a deterministic description of gross shape,

iii. formulating a random description of microstructure, and

iv. incorporating the imaging system characteristics, the gross shape and the microstructure to form the model; and

b. performing a random phasor sum representation of the physical model to form the probabilistic model.

47. A computer readable medium that stores a program to form a physically-based, probabilistic model for ultrasonic images, the program comprising:

a. means for creating a physical model of image formation; and

b. means for performing a random phasor sum representation of the physical model to form the probabilistic model.

48. A computer readable medium that stores a program to form an imaging model, the program comprising:

a. means for forming imaging system characteristics;

b. means for forming shape;

c. means for forming microstructure; and

d. means for incorporating the imaging system characteristics, the shape and the microstructure to create the imaging model.

49. A computer readable medium that stores a program to perform image pixel based statistics, the program comprising:

a. means for computing an amplitude mean value, an amplitude variance value and a ratio of the amplitude mean to a standard deviation value at each image pixel to develop a statistical image characterizing tissue;

b. means for classifying each image pixel as Rayleigh or Gaussian depending on the ratio of the amplitude mean to the standard deviation value;

c. means for assigning a density function to each image pixel based upon the classification of each image pixel; and

d. means for constructing the data likelihood as a product of the density functions.

50. A computer readable medium that stores a program to form a physically-based, probabilistic model for ultrasonic images, the program comprising:

a. means for creating a physical model of image formation, including:

i. means for developing a deterministic description of imaging system characteristics,

ii. means for developing a deterministic description of gross shape,

iii. means for developing a random description of microstructure, and

iv. means for incorporating the imaging system characteristics, the gross shape and the microstructure to form the physical model; and

b. means for performing a random phasor sum representation of the physical model to form the probabilistic model.